

TABLE 4
Ongoing SITE Emerging Technology Program Projects as of December 1996

Developer	Technology	Technology Contact	EPA Project Manager	Applicable Waste Media	Applicable Waste	
					Inorganic	Organic
ABB Environmental Services, Inc., Wakefield, MA (E06)*	Anaerobic-Aerobic Sequential Bioremediation of PCE	Willard Murray 617-245-6606	Ronald Lewis 513-569-7856	Groundwater	Not Applicable	PCE, TCE, DCE, Vinyl Chloride
Arizona State University/ Zentox Corporation, Tempe, AZ (E06)	Photocatalytic Oxidation with Air Stripping	Gregory Raupp 602-965-2828 Craig Turchi 352-867-7482	Norma Lewis 513-569-7665	Air Streams	Not Applicable	VOCs
Atomic Energy of Canada Limited, Chalk River, Ontario, Canada (E01)	Ultrasonic-Aided Leachate Treatment	Shiv Vijayan Les Moschuk 613-584-3311 ext. 3220/6057	Joan Mattox 513-569-7624	Acid Mine Drainage	Heavy Metals, Radionuclides	Not Applicable
Electrokinetics, Inc., Baton Rouge, LA (E08)	In Situ Bioremediation by Electrokinetic Injection	Elif Acar 504-753-8004	Randy Parker 513-569-7271	Soil, Sludge, Sediment	Heavy Metals	Nonspecific Organics
M.L. ENERGIA, Inc., Princeton, NJ (E07)	Reductive Thermal and Photo-Thermal Oxidation Processes for Enhanced Conversion of Chlorocarbons	Moshe Lavid 609-799-7970	Michelle Simon 513-569-7469	Air Streams	Not Applicable	Volatile Chlorinated Hydrocarbons
General Atomics, Nuclear Remediation Technologies Division, San Diego, CA (E06)	Acoustic Barrier Particulate Separator	Robert Goforth 619-455-4057 619-455-2984	Ronald Lewis 513-569-7856	Gas Streams	Metal and Radionuclide Particles	Nonspecific Organic Particles
Geo-Microbial Technologies, Inc., Ochelata, OK (E07)	Metals Release and Removal from Wastes	Donald Hitzman 918-535-2281	Jack Hubbard 513-569-7507	Soil, Sediment, Sludge	Metals	Nonspecific Organics
High Voltage Environmental Applications, Inc., Miami, FL (E06)	High-Energy Electron Beam Irradiation	William Cooper 305-593-5330	Mary Stinson 908-321-6683	Soil, Sediment, Sludge, Groundwater	Not Applicable	Pesticides, Insecticides, Petroleum Residues, PCBs
Institute of Gas Technology, Des Plaines, IL (E07)	Supercritical Extraction/Liquid Phase Oxidation	Anil Goyal 847-768-0605 Michael Mensinger 847-768-0602	Brunilda Dávila 513-569-7849	Soil, Sludge	Not Applicable	PAHs, PCBs, Other Organics

* Solicitation number

TABLE 4 (Continued)
Ongoing SITE Emerging Technology Program Projects as of December 1996

Developer	Technology	Technology Contact	EPA Project Manager	Applicable Waste Media	Applicable Waste	
					Inorganic	Organic
IT Corporation, Cincinnati, OH (E07)	Chelation/Electro-deposition of Toxic Metals from Soils	Radha Krishnan 513-782-4700	George Moore 513-569-7991	Soil, Sludge	Heavy Metals	Not Applicable
KSE, Inc., Amherst, MA (E08)	Adsorption-Integrated-Reaction Process	J.R. Kittrell 413-549-5506	Vince Gallardo 513-569-7176	Air Streams	Not Applicable	VOCs
OHM Remediation Services Corporation, Findlay, OH (E05)	Oxygen Microbubble In Situ Bioremediation	Douglas Jerger 419-424-4932	Ronald Lewis 513-569-7856	Groundwater	Not Applicable	Petroleum Hydrocarbons, VOC, SVOCs
Phytokinetics, Inc., North Logan, UT (E08)	Phytoremediation of Contaminated Soils	Ari Ferro 801-750-0985	Steven Rock 513-569-7149	Soil	Not Applicable	PCP, PAHs, Chlorinated Solvents, Insecticides, Nitroaromatic Explosives
Pintail Systems, Inc., Aurora, CO (E08)	Biominaleralization of Metals	Leslie Thompson 303-367-8443	Ronald Lewis 513-569-7856	Soil, Sludge, Sediment, Acid Mine Drainage	Heavy Metals	Not Applicable
Pulse Sciences, Inc., San Leandro, CA (E06)	X-Ray Treatment of Organically Contaminated Soils	Vernon Bailey 510-632-5100	George Moore 513-569-7991	Soil	Not Applicable	VOCs, SVOCs, PCBs
TMA Thermo Analytical, Inc., Oak Ridge, TN (E07)	Segmented Gate System	Jeffrey Brown 423-483-0683	Joan Mattox 513-569-7624	Soil, Sludge, Sediment, Sand	Gamma-Ray Emitting Radionuclides	Not Applicable
University of Houston, Houston, TX (E07)	Concentrated Chloride Extraction and Recovery of Lead	Dennis Clifford 713-743-4266 Tim Newed 713-743-0751	Eugene Harris 513-569-7862	Soil	Lead	Not Applicable
University of Wisconsin-Madison, Madison, WI (E08)	Photoelectrocatalytic Degradation and Removal	Marc Anderson 608-262-2674 Charles Hill, Jr. 608-263-4593	Vince Gallardo 513-569-7176	Groundwater, Aqueous Waste Streams	Heavy Metals	Dissolved Organics

ABB ENVIRONMENTAL SERVICES, INC. **(Anaerobic-Aerobic Sequential Bioremediation of PCE)**

TECHNOLOGY DESCRIPTION:

ABB Environmental Services, Inc. (ABB-ES), has demonstrated that sequential anaerobic-aerobic biodegradation of tetrachloroethene (PCE) is feasible under the proper conditions. The anaerobic process can dechlorinate PCE completely; however, dechlorination of the least-chlorinated ethenes (1,2-dichloroethene [DCE] and vinyl chloride [VC]) is the slowest step in this process. Of the chlorinated ethenes, VC is the most amenable to treatment by aerobic cometabolic processes. Therefore, a two-step process is thought to be the most efficient treatment methodology to address highly chlorinated solvents.

The first step in the ABB-ES technology is anaerobic biodegradation, which rapidly dechlorinates PCE and trichloroethene (TCE) to produce DCE and VC. Since the anaerobic dechlorination of DCE and VC to ethene can be quite slow, a second, aerobic biodegradation step is

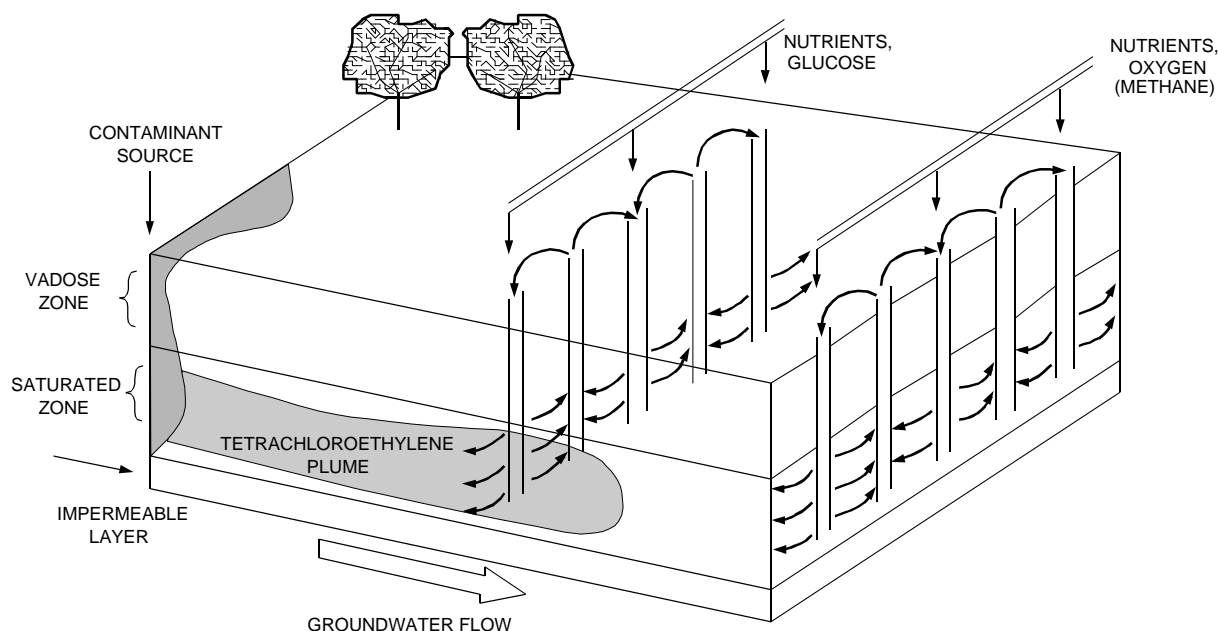
implemented that more quickly completes the remediation process. The schematic diagram below illustrates this technology.

WASTE APPLICABILITY:

This technology removes PCE, TCE, DCE, and VC from groundwater.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. ABB-ES will field-test its technology by creating and maintaining the proper in situ conditions for chlorinated ethene degradation in an aquifer. To achieve this goal, ABB-ES will test methods of carbon and mineral nutrient injection and delivery into an aquifer contaminated with PCE or TCE. Groundwater chemical conditions will be monitored within and downgradient of the anaerobic treatment zone to gauge the efficiency of the anaerobic



Anaerobic-Aerobic Sequential Bioremediation of PCE

process. If volatile organic compound analyses show that dechlorination of less-chlorinated ethenes is very slow under anaerobic conditions, oxygen and methane will be added to the groundwater to stimulate aerobic degradation by indigenous methanotrophic bacteria.

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ARIZONA STATE UNIVERSITY/ ZENTOX CORPORATION

(Photocatalytic Oxidation with Air Stripping)

TECHNOLOGY DESCRIPTION:

Chlorinated volatile organic compounds (VOC), such as trichloroethene (TCE) and perchloroethene (PCE), are readily removed from groundwater and soil using established methods such as air stripping and vapor extraction. However, this solution produces a VOC-contaminated air stream that requires further treatment.

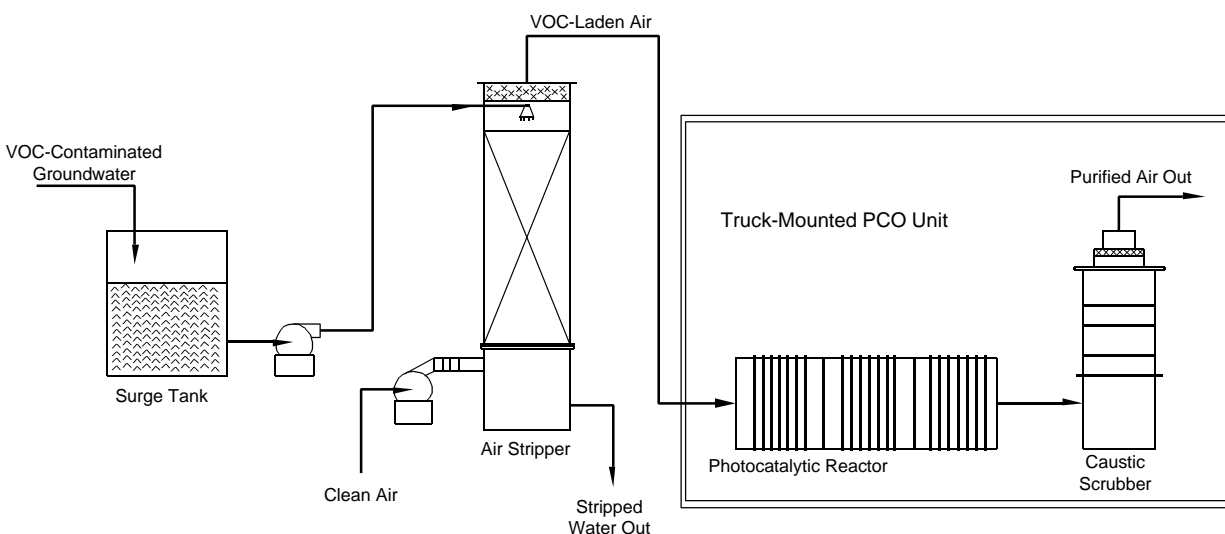
In gas-solid photocatalytic oxidation (PCO), the VOC-laden air stream is brought in contact with a titania catalyst and near-ultraviolet (UV) light. The UV light activates the catalyst, producing oxidizing radicals. The VOCs are completely destroyed to carbon dioxide and water in an oxidation reaction that occurs at or near room temperature. The treatment of chlorinated organics also produces hydrochloric acid.

Arizona State University (ASU) is investigating an integrated pilot-scale pump-and-treat system in

which chlorinated VOCs are transferred to an air stream using air stripping. A PCO reactor installed downstream from the air stripping unit treats the contaminated air stream. The figure below illustrates this system. The PCO unit incorporates a flow-through photocatalytic reactor for VOC destruction and a caustic absorber bed for removal of hydrochloric acid. The acid is neutralized to sodium chloride in the absorber bed.

PCO offers the following advantages over conventional treatment technologies:

- The photocatalytic process allows VOCs to be oxidized at or near room temperature.
- Low-temperature operation allows the use of plastic piping and construction, reducing costs and minimizing acid corrosion problems.
- Chemical additives are not required.



Photocatalytic Oxidation with Air Stripping

- The titania catalyst and fluorescent UV lamps are inexpensive and commercially available (modified catalyst formulations are available for enhanced performance).
- A variety of halogenated and nonhalogenated organic compounds can be completely oxidized to innocuous or easily neutralized products, such as carbon dioxide and hydrochloric acid.

WASTE APPLICABILITY:

This technology can treat VOC-contaminated streams produced by air stripping contaminated groundwater or soil vapor extraction of contaminated soil. The technology is appropriate for dilute VOC concentrations (such as 500 parts per million by volume or less) and low to moderate flow rates. Laboratory data indicate that the PCO technology can also be adapted to industrial facilities that emit dilute VOC-contaminated air streams. Candidates include chemical process plants, dry cleaners, painting operations, solvent cleaning operations, and wastewater and hazardous waste treatment facilities. Air in closed environments could also be purified by integrating PCO units with heating, ventilation, and air conditioning systems.

STATUS:

The PCO technology was accepted into the SITE Emerging Technology Program in 1993. Under the program, ASU has conducted bench-scale tests to evaluate the integration of a PCO unit downstream of an existing air stripping unit. Results of the bench-scale testing have provided design data for a pilot-scale test at a Phoenix, Arizona Superfund site that is contaminated with chlorinated VOCs. ASU's previous laboratory studies indicate rapid destruction to nondetectable levels (98 to 99 percent removal) of various concentrations of TCE and other chlorinated ethenes in humid air streams.

In 1995, Zentox Corporation (Zentox) fielded a prototype PCO system for the treatment of TCE in air. Building on the data gained from that system, Zentox is fabricating a second generation system for use at the Phoenix site. Following tests at the Phoenix site, this 50- to 100-cubic-feet-per-minute pilot plant unit will be available for trials at other locations.

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ATOMIC ENERGY OF CANADA LIMITED (Ultrasonic-Aided Leachate Treatment)

TECHNOLOGY DESCRIPTION:

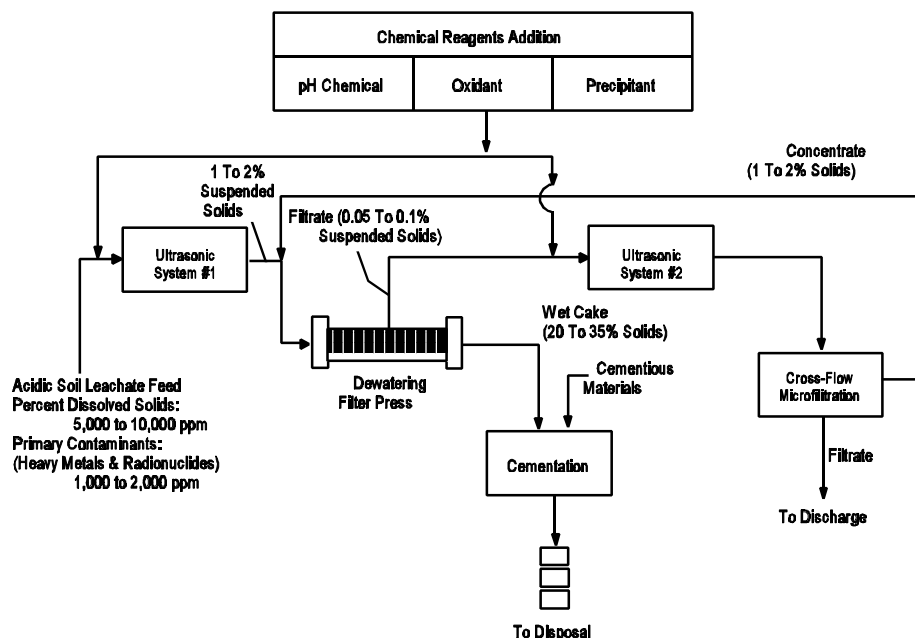
The ultrasonic-aided leachate treatment process involves enhanced chemical treatment of acidic soil leachate solutions. These solutions, also known as acid mine drainage, are caused by the oxidation and dissolution of sulfide-bearing wastes, which produces sulfuric acid. The resulting acidic water leaches metal contaminants from the exposed waste rock and mine tailings, creating large volumes of toxic acidic leachates.

The ultrasonic-aided leachate treatment process uses an ultrasonic field to improve contaminant removal through precipitation, coprecipitation, oxidation, ion scavenging, and sorption (see figure below). These processes are followed by solid-liquid separation by filtration equipment using a filter press and a cross-flow microfilter connected in series. The time required for treatment depends on (1) the nature of acidic waste to be treated, (2) the treated water quality with respect to contaminant concentration, and (3) the rate at which the physical and chemical

processes occur. The treatable leachate volume is scalable.

The major difference between this technology and conventional processes is the use of ultrasonic mixing instead of mechanical agitation in large tanks. Research indicates that an ultrasonic field significantly increases both the conversion rate of dissolved contaminants to precipitates and the rate of oxidation and ion exchange. Earlier studies by Atomic Energy of Canada Limited (AECL) revealed that the time required to precipitate heavy metals from aqueous solutions decreased by an order of magnitude in the presence of an ultrasonic field.

The ultrasonic-aided leachate treatment process is compact, portable, and energy-efficient. Safety and process controls are built in as necessary for handling mixed radioactive solutions. This process also generates minimal fugitive emissions and produces a treated effluent that meets applicable discharge limits. The process may be able to treat waste containing small amounts of dissolved or



Ultrasonic-Aided Leachate Treatment
for Acidic Soil Leachate Solutions

suspended organics.

WASTE APPLICABILITY:

The ultrasonic-aided leachate treatment process treats acid mine drainage contaminated with heavy metals and radionuclides. The process can also be combined with soil remediation technologies.

STATUS:

The ultrasonic-aided leachate treatment process was accepted into the SITE Emerging Technology Program in 1993. Under this program, AECL is developing and testing a pilot-scale unit to treat acidic soil leachate solutions containing low levels of metals and radionuclides.

The quality assurance and test plan was approved in October 1994. Laboratory-scale testing using acidic leachates from the Berkeley Pit in Butte, Montana and from Stanleigh Mines in Elliot Lake, Ontario, Canada is complete. The tests were designed to find optimal single and multistage treatment regimes to remove from the leachates a variety of dissolved species (iron, aluminum, manganese, magnesium, copper, zinc, uranium, radium, and sulfate), either as contaminants or as reusable resources.

Given optimum process chemistry, low energy (less than 5 kilojoules per liter) and low frequency (20 kilohertz) ultrasonic cavitation fields were sufficient to remove the dissolved species to levels meeting discharge requirements.

The energy input corresponds to a chemical conditioning time of a few seconds to tens of seconds. The underlying principles examined include lime and limestone precipitation, copper cementation, iron, and uranium oxidation, ion sorption, and ion scavenging.

A Phase 1 interim report summarizing the laboratory-scale results was issued in August 1995. A revised Phase 1 report was issued in February 1996. Testing of the pilot-scale system is scheduled to be complete in December 1996.

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ELECTROKINETICS, INC. (In Situ Bioremediation by Electrokinetic Injection)

TECHNOLOGY DESCRIPTION:

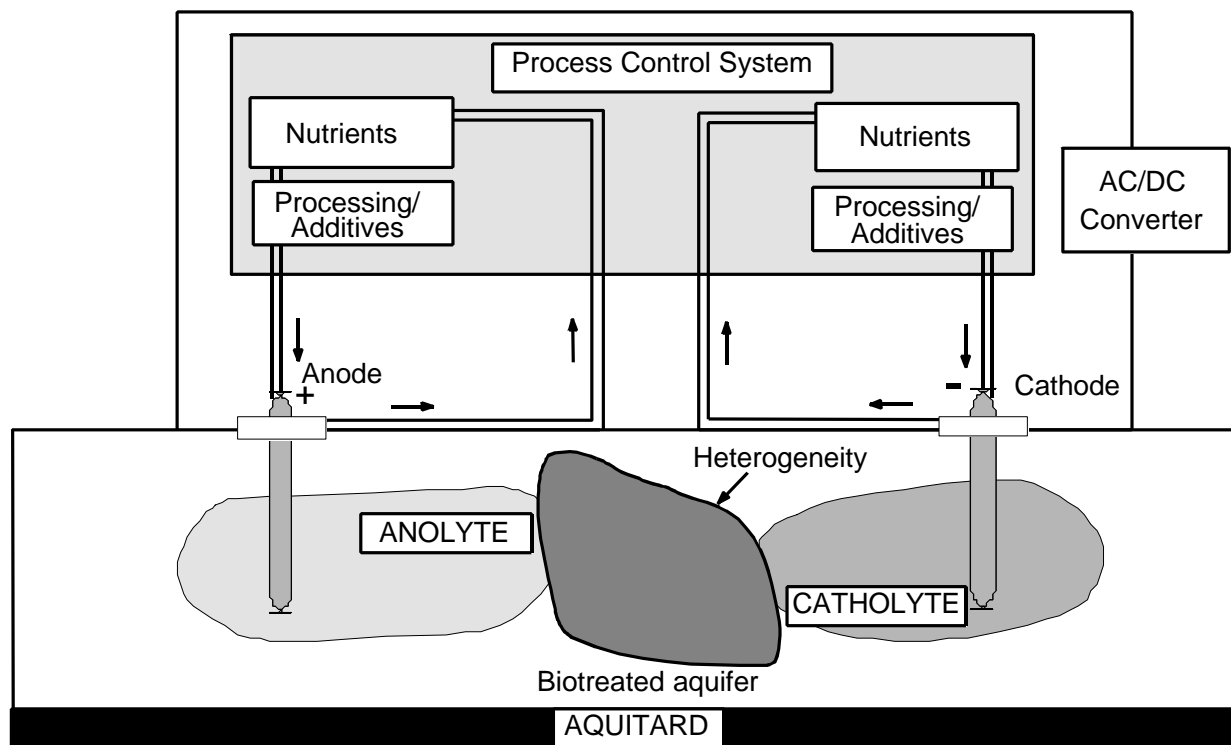
In situ bioremediation is the process of introducing process nutrients into biologically active zones (BAZ). These nutrients are usually introduced by pumping recirculated groundwater through the BAZ, relying on hydraulic gradients or the permeability of the BAZ. However, heterogeneities in aquifers often hinder the introduction of the nutrients. For example, areas with higher permeability result in preferential flow paths, leading to incomplete biological treatment. The inability to uniformly introduce nutrients and other additives, such as surfactants and cometabolites, has hindered the successful implementation of in situ bioremediation.

Electrokinetics, Inc. (Electrokinetics), is developing an electrokinetic remediation technology that stimulates and sustains in situ bioremediation for treatment of organics and heavy metals. The technology involves applying to soil or groundwater

a low-level direct current (DC) electrical potential difference or an electrical current using electrodes placed in an open or closed flow arrangement. Groundwater or an externally supplied processing fluid is used as the conductive medium. The low-level DC causes physicochemical and hydrological changes in both the waste and the conductive medium, thereby enabling uniform transport of process additives and nutrients into the BAZ, as shown in the figure below.

The Electrokinetics technology is designed to overcome the problems associated with aquifer heterogeneities, unlike conventional in situ injection by hydraulic techniques. The rate of nutrient and additive transport under electrical gradients is at least one order of magnitude greater than that achieved under chemical gradients.

WASTE APPLICABILITY:



Schematic Diagram of In Situ Bioremediation by Electrokinetic Injection

Electrokinetic injection can be used for any waste that can be treated by bioremediation. The technique allows in situ treatment of contaminated subsurface deposits, sediments, and sludges. The technology can be engineered to remove inorganics through electromigration and electroosmosis, while process additives and nutrients are added to the processing fluids to enhance bioremediation of organics.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1995. Pilot-scale studies under the Emerging Technology Program will be used to develop operating parameters and to demonstrate the efficiency and cost-effectiveness of the technology during a full-scale application. The SITE evaluation may take place in 1997 at a military base or a U.S. Department of Energy site.

Electrokinetics is studying enhancement techniques to remove, or prevent the formation of, precipitates near the cathode during removal of inorganics. A 1993 study suggested that adding acetic acid may depolarize the cathode reaction, preventing precipitate formation. This study was conducted by Electrokinetics and Argonne National Laboratory under a U.S. Department of Defense Small Business Innovative Research grant. The study assessed nutrient movement through clean soils of different hydraulic conductivities; samples for the study were taken from Idaho National Engineering Laboratory and the Savannah River Site. Currently, bench- and pilot-scale tests are being conducted on soils containing trichloroethene and hydrocarbons of interest.

Electrokinetics has remediated several sites in conjunction with its proprietary electrode system (CADEX™ electrodes). Under a Small Business Innovative Research grant from the U.S. Waterways Experiment Station, Electrokinetics has tested its technology on soils from Fort Polk in Louisiana, and the Naval Depot in Hastings, Nebraska. Current activities include movement of biological additives through mixed soil horizons and directing these additives to sources of organic compounds for electrokinetically enhanced degradation.

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M.L. ENERGIA, INC.
**(Reductive Thermal and Photo-Thermal Oxidation Processes
for Enhanced Conversion of Chlorocarbons)**

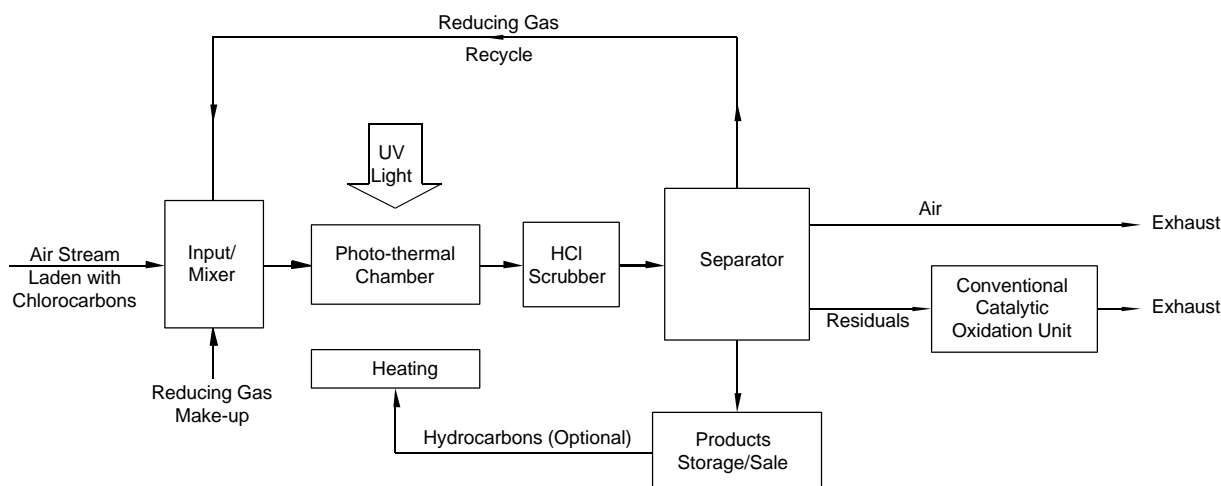
TECHNOLOGY DESCRIPTION:

Two innovative processes, Reductive Thermal Oxidation (RTO) and Reductive Photo-Thermal Oxidation (RPTO), are designed to safely and cost-effectively convert chlorinated hydrocarbons (CIHC) into environmentally benign and useful materials in the presence of a reducing atmosphere. Both processes have evolved from M.L. Energia, Inc.'s, Reductive Photo-Dechlorination (RPD) technology, which does not permit the presence of air (oxygen).

The RTO/RPTO processes treat air streams laden with CIHCs. RTO converts CIHCs at moderate temperatures by cleaving carbon-chlorine bonds in the absence of ultraviolet light. RPTO operates under similar conditions but in the presence of ultraviolet light. Subsequent reactions between ensuing radicals and the reducing gas results in chain-propagation reactions. The presence of air (oxygen) during the conversion process accelerates the overall reaction rate without significant oxidation. The final products are useful hydrocarbons (HC) and environmentally safe

materials including hydrogen chloride, carbon dioxide, and water.

The RTO/RPTO processes are shown in the figure below. The process consists of six main units: (1) input/mixer; (2) photo-thermal chamber; (3) scrubber; (4) separator; (5) storage/sale; and (6) conventional catalytic oxidation unit. Air laden with CIHCs is mixed with reducing gas and passed into a photo-thermal chamber, which is unique to the RTO/RPTO technology. In this chamber, the mixture is heated to moderate temperatures to sustain the radical chain reactions. Depending on the physical and chemical characteristics of the particular CIHCs treated, conversion can take place in two ways: the RTO process is purely thermal, and the RPTO process is photo-thermal. After suitable residence time, HCl is removed by passing the stream through an aqueous scrubber. The stream can then be treated in an optional second storage, or separated and sent to storage. Excess reducing gas is recycled, and residual (sub parts per million) CIHCs, HCs, and CO are treated by catalytic oxidation. Volatile hydrocarbons can also be recycled as an energy source for process



Reductive Thermal Oxidation (RTO)
and Photo-Thermal Oxidation (RPTO) Processes

heating, if partial oxidation at the photo-thermal chamber does not generate enough heat.

WASTE APPLICABILITY:

This technology is designed to remove volatile hydrocarbons from air streams. Field applications include direct treatment of air streams contaminated with chlorocarbons, wastes discharged from soil vapor extraction or vented from industrial hoods and stacks, and those adsorbed on granular activated carbon. M.L. ENERGIA, Inc., claims that the process can also be applicable for in situ treatment of sites containing contaminated surface waters and groundwaters. The process has not yet been tested on these sites.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. During the first year, laboratory-scale tests were conducted on two saturated CIHCs (dichloromethane and trichloroethane) and on two representatives of unsaturated CIHCs (1,2-dichloroethene and trichloroethene). The RTO/RPTO processes have demonstrated 99 percent or more conversion/dechlorination with high selectivity towards saleable hydrocarbon products (methane and ethane). During the second year, a field demonstration will be conducted with a pilot-scale prototype unit, followed by performance evaluation and cost analysis.

These processes will be available for commercialization after the completion of the field demonstration.

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GENERAL ATOMICS, NUCLEAR REMEDIATION TECHNOLOGIES DIVISION (Acoustic Barrier Particulate Separator)

TECHNOLOGY DESCRIPTION:

The acoustic barrier particulate separator separates particulates in a high temperature gas flow. The separator produces an acoustic waveform directed against the gas flow, causing particulates to move opposite the flow. The particulates drift to the wall of the separator, where they aggregate with other particulates and precipitate into a collection hopper. The acoustic barrier particulate separator differs from other separators by combining both high efficiency and high temperature capabilities.

The figure below presents a conceptual design. High temperature inlet gas flows through a muffler chamber and an agglomeration segment before entering the separation chamber. In the separation chamber, particulates stagnate due to the acoustic force and drift to the chamber wall, where they collect as a dust cake that falls into a collection hopper. The solids are transported from the collection hopper by a screw-type conveyor against a clean purge gas counterflow. The purge gas cools the solids and guards against contamination of particulates by inlet-gas volatiles in the process stream.

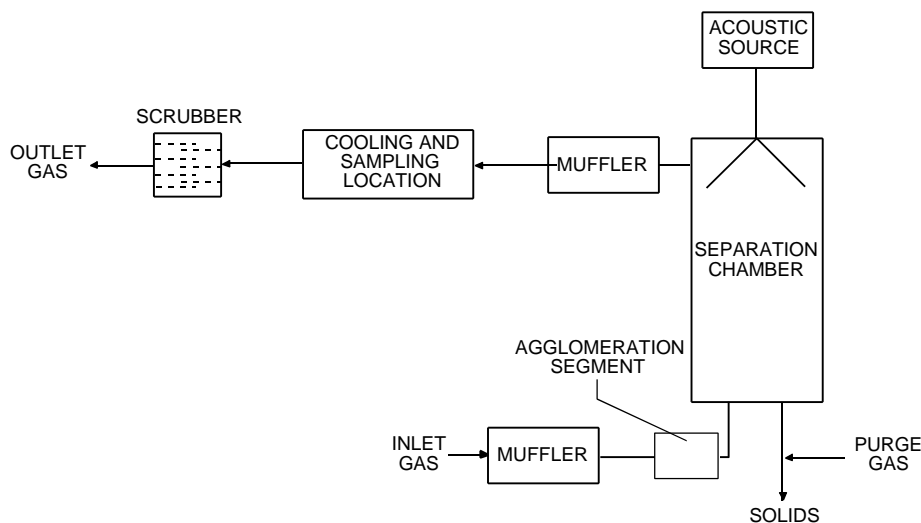
The gas flows past the acoustic source and leaves

the separation chamber through an exit port. The gas then passes through another muffler chamber and flows through sections where it is cooled and any remaining gas-borne particulate samples are collected. Finally, the gas is further scrubbed or filtered as necessary before it is discharged.

The separator can remove the entire range of particle sizes; it has a removal efficiency of greater than 90 percent for submicron particles and an overall removal efficiency of greater than 99 percent. Due to the large diameter of the separator, the system is not prone to fouling.

WASTE APPLICABILITY:

This technology can treat off-gas streams from thermal desorption, pyrolysis, and incineration of soil, sediment, sludges, other solid wastes, and liquid wastes. The acoustic barrier particulate separator is a high-temperature, high-throughput process with a high removal efficiency for fine dust and fly ash. It is particularly suited for thermal processes where high temperatures must be maintained to prevent condensation onto particulates. Applications include removal of gas-borne solids during thermal treatment of



Acoustic Barrier Particulate Separator

semivolatile organics, such as polychlorinated biphenyls, and gas-phase separation of radioactive particles from condensable hazardous materials.

STATUS:

The acoustic barrier particulate separator was accepted into the SITE Emerging Technology Program in 1993. The principal objective of this project will be to design, construct, and test a pilot-scale acoustic barrier particulate separator that is suitable for parallel arrangement into larger systems. The separator will be designed for a flow of 300 cubic feet per minute and will be tested using a simulated flue gas composed of heated gas and injected dust.

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GEO-MICROBIAL TECHNOLOGIES, INC.
(Metals Release and Removal from Wastes)

TECHNOLOGY DESCRIPTION:

Geo-Microbial Technologies, Inc., has developed an anaerobic biotreatment technology to release metals from liquefaction catalyst wastes derived from spent coal that are also contaminated with complex organic compounds. This anaerobic metals release (AMR) technology may be adapted to treat other wastes with metals contamination.

Current biohydrometallurgy systems use aerobic acidophilic bacteria, which oxidize mineral sulfides while solubilizing metals and forming large amounts of acid. This aerobic process can result in acidic drainage from natural sources of metal sulfides. For example, acidophilic bacteria convert the pyrite and iron-containing minerals in coal into oxidized iron and sulfuric acid. The acid then further solubilizes the pyrite and other sulfide minerals. The result is contamination of streams and lakes due to acidification and an increase in soluble heavy metals.

The AMR technology operates anaerobically and at a near-neutral pH, employing anaerobic *Thiobacillus* cultures in consortium with heterotrophic denitrifying cultures. The diversity of the inhabiting denitrifiers allows multiple carbon sources, including some organic pollutants, to be used and treated.

The anaerobic environment is adjusted by introducing low levels of nitrate salts that function as an alternate electron acceptor source, selectively enhancing the inherent denitrifying microflora.

This process increases the denitrifying population that releases the metals. The soils containing the metals are then flooded with the dilute nitrate solutions. These improved anaerobic leaching solutions permeate the soils, allowing the metals to be solubilized into the leachate by the microbial consortium. The nitrate concentration is adjusted so that the effluent is free of nitrate; the nitrate concentration is monitored so that the process operation can be closely controlled. The solubilized metals in the leachate are recaptured by established processes, and the metal-free effluent is recycled within the process. The nitrate-based ecology has the added advantage of decreasing levels of sulfate-reducing bacteria and sulfide generation.

The versatility and low operating constraints of the AMR technology offer multiple process options. The technology can be adapted for in situ flooding or modified to flood a waste pile in a heap-leaching operation. The elimination of any aeration requirement allows the process to be easily designed and considered for bioslurry applications. Thus, the technology offers a greater range of treatment applications for environmental waste situations that were considered difficult to treat.

WASTE APPLICABILITY:

The AMR technology targets toxic metal-contaminated soils, sludges, and sediments, which can also be contaminated with other wastes, including hydrocarbons and organic pollutants. While metals are the primary pollutant treated, the biological system is also designed to degrade and remove associated organic contaminants.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. Studies under the Emerging Technology Program will evaluate how effectively the AMR technology removes metals from soil.

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HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC. (High-Energy Electron Beam Irradiation)

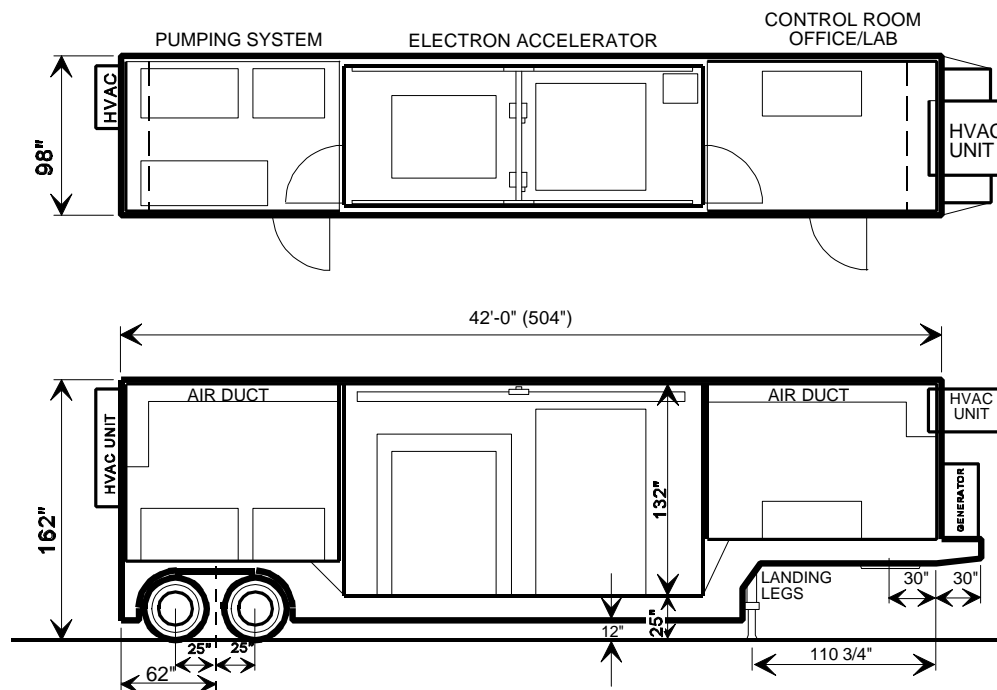
TECHNOLOGY DESCRIPTION:

The high-energy electron beam irradiation technology is a low-temperature method for destroying complex mixtures of hazardous organic chemicals in hazardous wastes. These wastes include slurried soils, river or harbor sediments, and sludges. The technology can also treat contaminated soils and groundwater.

The figure below illustrates the mobile electron beam treatment system. The system consists of a computer-automated, portable electron beam accelerator and a delivery system. The 500-kilovolt electron accelerator produces a continuously variable beam current from 0 to 40 milliamperes. At full power, the system is rated at 20 kilowatts. The waste feed rate and beam current can be varied to obtain doses of up to 2,000 kilorads in a one-pass, flow-through mode.

The system is trailer-mounted and is completely self-contained, including a 100-kilowatt generator for remote locations or line connectors where power is available. The system requires only a mixing tank to slurry the treatable solids. The system also includes all necessary safety checks.

The computerized control system continuously monitors the waste feed rate, absorbed dose, accelerator potential, beam current, and all safety shutdown features. The feed rate is monitored with a calibrated flow valve. The absorbed dose is estimated based on the difference in the temperature of the waste stream before and after irradiation. The system is equipped with monitoring devices that measure the waste stream temperature before and after irradiation. Both the accelerating potential and the beam current are obtained directly from the transformer.



Mobile Electron Beam Treatment System

Except for slurring, this technology does not require pretreatment of wastes.

WASTE APPLICABILITY:

This technology treats a variety of organic compounds, including wood-treating chemicals, pesticides, insecticides, petroleum residues, and polychlorinated biphenyls (PCB) in slurried soils, sediments, and sludges.

STATUS:

High Voltage Environmental Applications, Inc. (HVEA), was accepted into the SITE Emerging Technology Program in 1993. Under this program, HVEA will demonstrate its mobile pilot plant on soils, sediments, or sludges at various hazardous waste sites. Candidate sites are being identified. On-site studies will last up to 2 months.

Initial studies by HVEA have shown that electron beam irradiation effectively removes 2,4,6-trinitrotoluene from soil slurries.

As part of the Emerging Technology Program, HVEA has identified 350 tons of soil contaminated with an average Aroclor 1260 concentration of approximately 1,000 milligrams per kilogram. A small 1-ton feasibility study occurred in August 1995. After results are available from the 1-ton study, HVEA plans to make its mobile unit available for full-scale remediations.

In a recent bench-scale study, a multisource hazardous waste leachate containing 1 percent dense nonaqueous phase liquid was successfully treated. In another bench-scale study, a leachate containing a light nonaqueous phase liquid contaminated with PCBs was treated to F039 standards.

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INSTITUTE OF GAS TECHNOLOGY (Supercritical Extraction/Liquid Phase Oxidation)

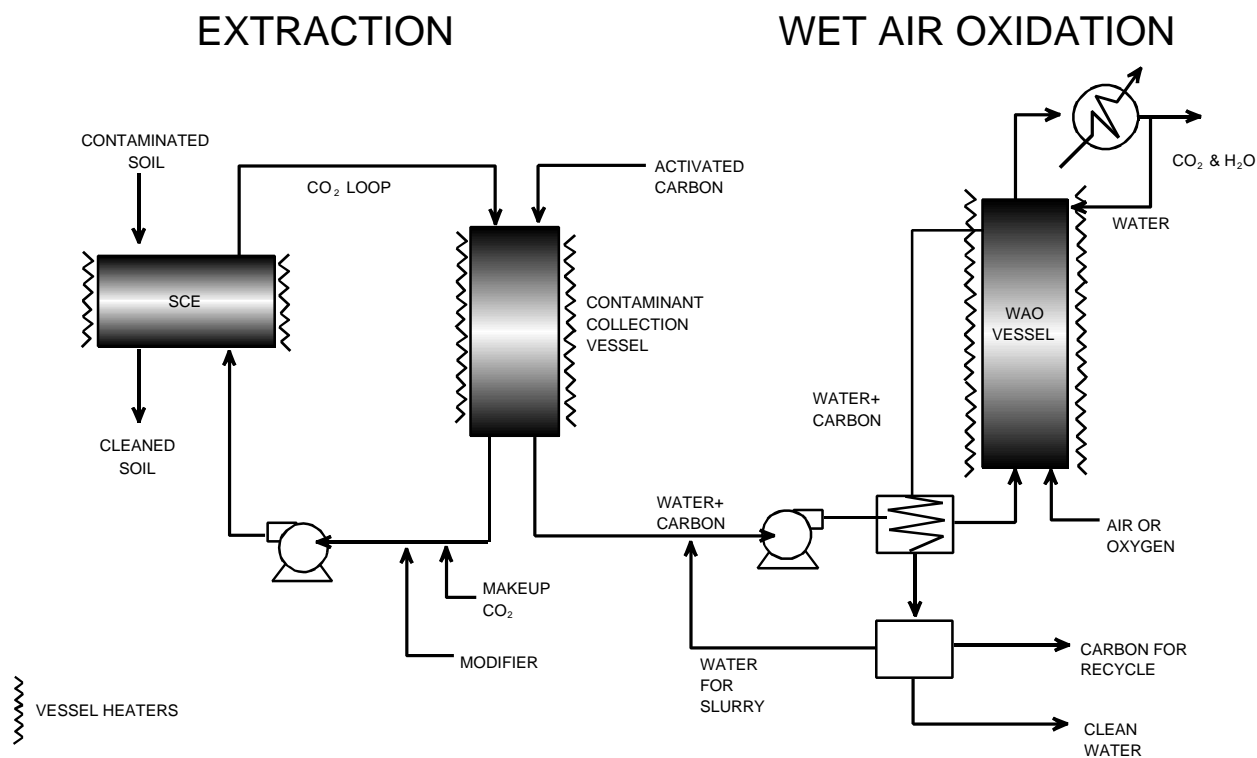
TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology's (IGT) Supercritical Extraction/Liquid Phase Oxidation (SELPhOx) process (see figure below) removes organic contaminants from soils and sludges and destroys them. SELPhOx combines two processing steps: (1) supercritical extraction (SCE) of organic contaminants in liquids, and (2) wet air oxidation (WAO) destruction of the contaminants. The two-step process, linked by a contaminant collection stage, offers great flexibility for removing and destroying both high and low concentrations of organic contaminants.

Combining SCE and WAO in a single two-step process allows development of a highly efficient and economical process for remediating contaminated soils. Supercritical extraction with carbon dioxide (CO_2) removes organic contaminants from the soil and transfers them to an aqueous phase while

leaving much of the original soil organic matrix in place. The contaminants are then collected on activated carbon in a contaminant collection vessel. The activated carbon with sorbed contaminants is then transported in an aqueous stream to a WAO reactor for destruction. Concentrating the organic contaminants on activated carbon in water provides a suitable matrix for the WAO feed stream and improves process economics by decreasing WAO reactor size. The activated carbon is regenerated in the WAO reactor with minimal carbon loss and can be recycled to the contaminant collection vessel.

The SELPhOx process requires only water, air, makeup activated carbon, and the extractant (CO_2). Primary treatment products include cleaned soil, water, nitrogen (from the air fed to the WAO step), and CO_2 . Organic sulfur, nitrogen, and chloride compounds that may be present in the original soil or sludge matrix are transformed to relatively innocuous compounds in the product water. These



Supercritical Extraction/Liquid Phase Oxidation (SELPhOx) Process

compounds include sulfuric acid and hydrogen chloride, or their salts. The treated soil can be returned to the original site, and the water can be safely discharged after thermal energy recovery and minor secondary treatment. The gas can be depressurized by a turbo expander for energy recovery and then vented through a filter.

WASTE APPLICABILITY:

The SELPhOx process removes organic contaminants from soils and sludges, including chlorinated and nonchlorinated polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls, and other organic contaminants. The process is targeted toward sites that are contaminated with high levels of these organics (hot spots).

STATUS:

The SELPhOx process was accepted into the SITE Emerging Technology Program in July 1994. The primary objectives of the project are to (1) evaluate SCE's contaminant removal efficiency, (2) determine the potential for CO₂ recovery and reuse, and (3) determine destruction efficiencies of extracted contaminants in the WAO process. Analytical results from the project will provide the necessary information for the full-scale process design.

Laboratory-scale SCE tests have been completed using soils contaminated with PAHs. Operating conditions for the SCE stage and the activated carbon adsorption stage have been selected. A transportable field test unit has been constructed. Testing of this unit with PAH-contaminated soil is underway.

FOR FURTHER INFORMATION:

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IT CORPORATION

(Chelation/Electrodeposition of Toxic Metals from Soils)

TECHNOLOGY DESCRIPTION:

IT Corporation has conducted laboratory-scale research on an innovative process that removes heavy metals from contaminated soils and sludges by forming a soluble chelate. The metals and the chelating agent are then separated from the soils and recovered.

The treatment employs two key steps (see figure below): (1) a water-soluble chelating agent, such as ethylenediamine tetra acetic acid, bonds with heavy metals and forms a chelate; and (2) an electromembrane reactor (EMR) recovers the heavy metals from the chelate and regenerates the chelating agent.

Soils are screened before the chelation step to remove large particles such as wood, metal scrap, and large rocks.

The chelate is dewatered to separate the water-soluble chelating agent from the solid phase. The separated chelating agent, which contains heavy metals, is then treated in the EMR. The EMR

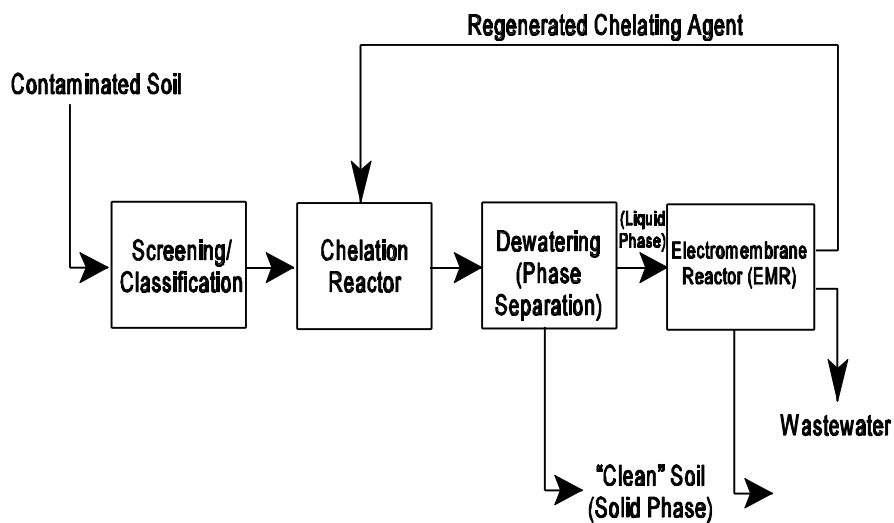
consists of an electrolytic cell with a cation transfer membrane separating the cathode and anode chambers.

WASTE APPLICABILITY:

The technology may be applicable to a wide variety of metal-contaminated hazardous wastes, including soils and sludges. Limited work has also been conducted to determine its effectiveness in removing cadmium from soils and sludges.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. The Jack's Creek site, located near Maitland, Pennsylvania, was selected for evaluation of the technology. The site was operated as a precious and nonprecious metal smelting and nonferrous metal recycling operation from 1958 to 1977. A portion of the property is currently operated as a scrap yard. The lead concentration in the contaminated soil used for the evaluation was approximately 2 percent. Toxicity characteristic leaching procedure (TCLP)



Simplified Process Flow Diagram of Treatment Process

analysis on the contaminated soil showed lead levels of 7.7 milligrams per liter (mg/L), which is above the regulatory limit of 5 mg/L. During the project, IT Corporation will establish appropriate conditions for removal of lead from the soil and reduce TCLP concentrations of lead in the soil to below regulatory levels.

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